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FINAL REPORT
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Comparison of Lightning Observations from the KSC LDAR System
with Radar Observations from the NCAR CP-2 Radar

Paul Krehbiel and William Rison
Geophysical Research Center - Langmuir Laboratory
New Mexico Institute of Mining and Technology
Socorro, New Mexico, 87801

This grant supported observations of thunderstorms at Kennedy Space Center during the summer of 1995. In particular, we obtained detailed observations of lightning-producing storms over KSC with the CP2 radar of the National Center for Atmospheric Research (NCAR), for the purpose of comparing these with observations from KSC's Lightning Detection and Ranging (LDAR) system. The NCAR radar was a special purpose dual-polarization system for studying the development of precipitation in storms and was at KSC for another project, the Small Cumulus Microphysics Study - SCMS. We used the radar on a non-interference basis to obtain the desired observations. The LDAR data were provided by Launa Maier and Carl Lennon of NASA KSC. In addition we recorded the electrostatic field change of the lightning discharges at two locations.

Good observations of developing and active thunderstorms were obtained in late July and early August of 1995, prior to Hurricane Erin. Subsequent to the field observational period we compared the LDAR lightning observations with the storm structure as indicated by the radar. This has produced quite nice results that have been reported in two conferences (Rison et al., 1995, 1996). In addition, a physics student, Mark Robison, analyzed observations for a large, complex storm system for his Master's Independent Study.

The results obtained to date are summarized briefly as follows: a) The initial lightning sequence in a small developing storm was observed to occur in a region of the storm where supercooled raindrops had frozen within the previous few minutes. This is consistent with the idea that the storm electrification is produced by interactions between ice particles. b) The lightning discharges tended to avoid regions of supercooled liquid raindrops, possibly indicating that corona from the drops reduces any electrification in the vicinity of the drops. c) 'Bilevel' lightning discharges within storms have been confirmed to be between the level of negative charge at mid-levels in the storm and the upper storm level. This is consistent with and expands upon our understanding that storms have a basic dipolar charge structure. d) The upward channels of the intracloud lightning discharges are often aligned with shafts of strong precipitation, and often begin just above the upper extent of 40 dBZ reflectivity in the precipiation shaft. This is consistent with a precipitation-based mechanism of electrification.

The observations have provided an excellent dataset and additional analyses are continuing.

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Comparison of Lightning and Radar Observations in a Small Storm at Kennedy Space Center, Florida.

William Rison and Paul Krehbiel, New Mexico Tech, Socorro, New Mexico, 87801, USA
Launa Maier and Carl Lennon, NASA/KSC, Kennedy Space Center, Florida, 32899, USA

In this paper we report observations in which lightning structure as determined by the Lightning Detection and Ranging (LDAR) system at Kennedy Space Center, Florida are compared with radar observations of storm structure using the CP2 radar of the National Center for Atmospheric Research. Initial results for a small storm on July 25, 1995 are summarized as follows:

1. Lightning began in the storm following 4 m s^{-1} vertical growth of the 20 dBZ echo top to above 10 km altitude MSL. The maximum height of the lightning radiation sources closely matched the subsequent growth and decay of the 20 dBZ echo top (Figure 1).

2. The initial discharge produced upward negative breakdown from 7.5 to 11.5 km altitude in a reflectivity cell on the far, southern side of the storm (Figure 2, bottom). The discharge occurred after liquid precipitation between 4 and 6 km altitude in that part of the storm had glaciated, as indicated by a decrease in differential reflectivity (ZDR) from an earlier scan (Figure 2, top). The 2nd and 3rd discharges were similar intracloud flashes that occurred 1-2 km in front of the Figure 2 scan plane, also above a region of precipitation that had glaciated.

3. Five minutes after the initial discharge, successive cloud-to-ground (CG) and intracloud (IC) flashes occurred as shown in Figure 3. Each occurred in the right-hand or southern part of the storm where precipitation above the 0 °C level was ice-form, and avoided the more strongly reflecting region that contained supercooled liquid drops on the left or northern side. The CG flash removed negative charge from a region of 45-50 dBZ reflectivity between 5.5 and 7 km altitude (-5 to -15 °C). The IC flash transported negative charge from just above this region into the upper part of the storm; its channels closely paralleled the reflectivity contours.

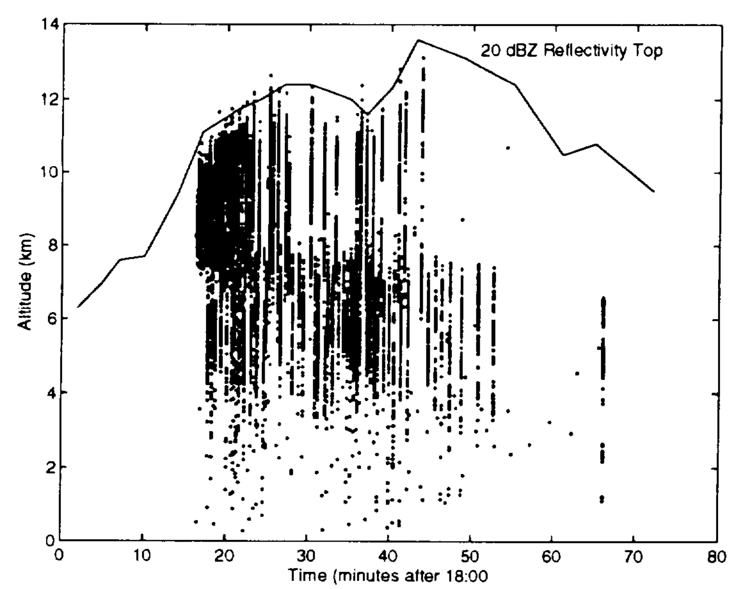

Figure 1. Height vs. time plot of lightning radiation sources and 20 dBZ echo top from small storm on July 25, 1995.

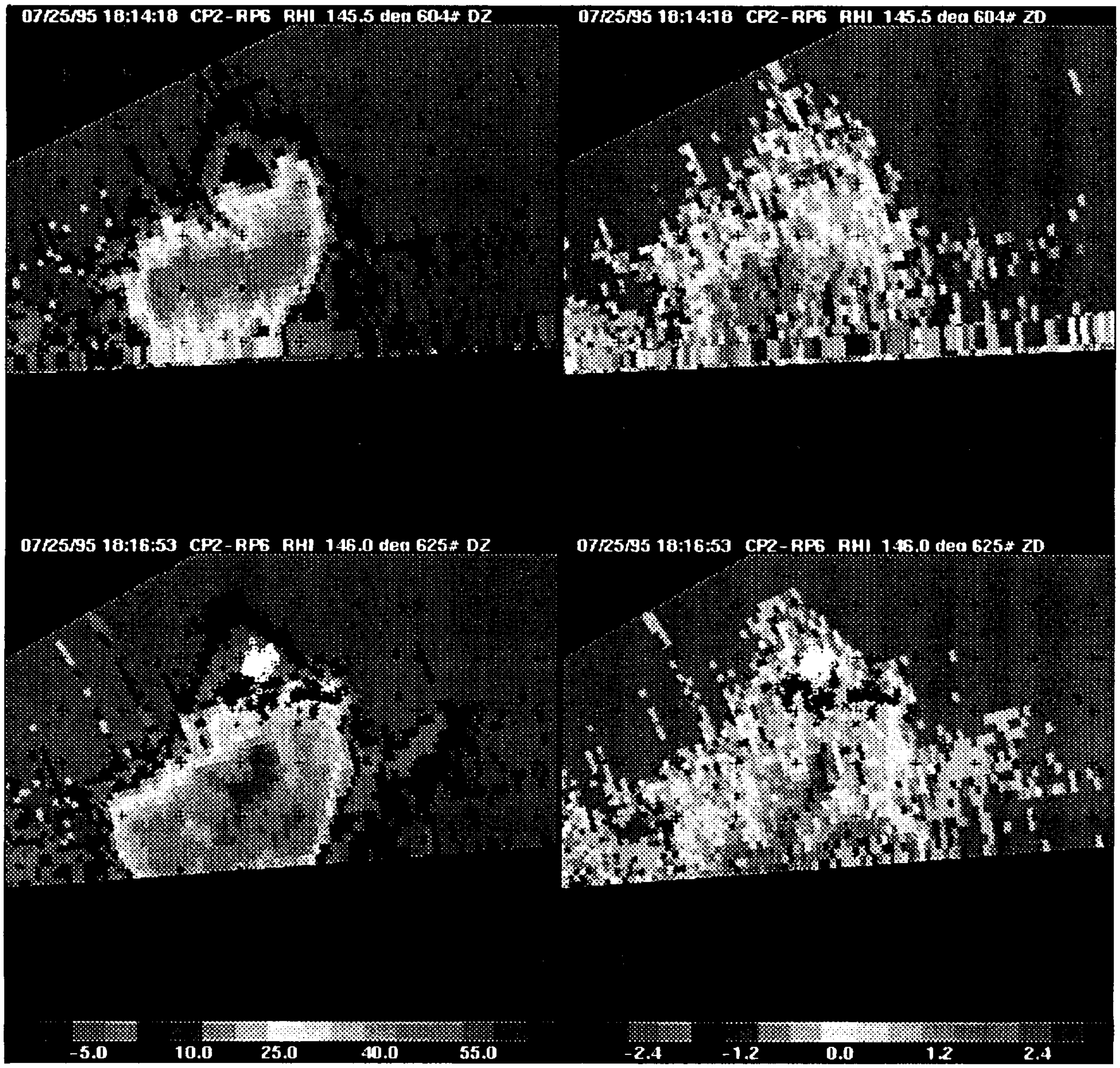

Figure 2. Vertical radar scans through the plane of the initial lightning discharge, 2 minutes before and 34 seconds after the initial discharge (top and bottom, respectively). The first discharge occurred in the reflectivity cell on the right-hand side of the storm, just beyond 26 km range in the left panels. Also shown are the 2nd and 3rd discharges, which occurred 1-2 km in front of the scan plane at 23 to 25 km range in the more vertically developed part of the storm. ZDR observations (right panels) show that the first discharge occurred above a region where supercooled liquid precipitation between 4.5 and 6 km altitude (0 and -10 °C) had glaciated since the earlier scan. The second and third discharges also occurred above glaciated precipitation. A localized region of supercooled liquid precipitation that had developed up to 6.5 km altitude in the radar scan plane at 25 km range tended to be avoided by the discharges.

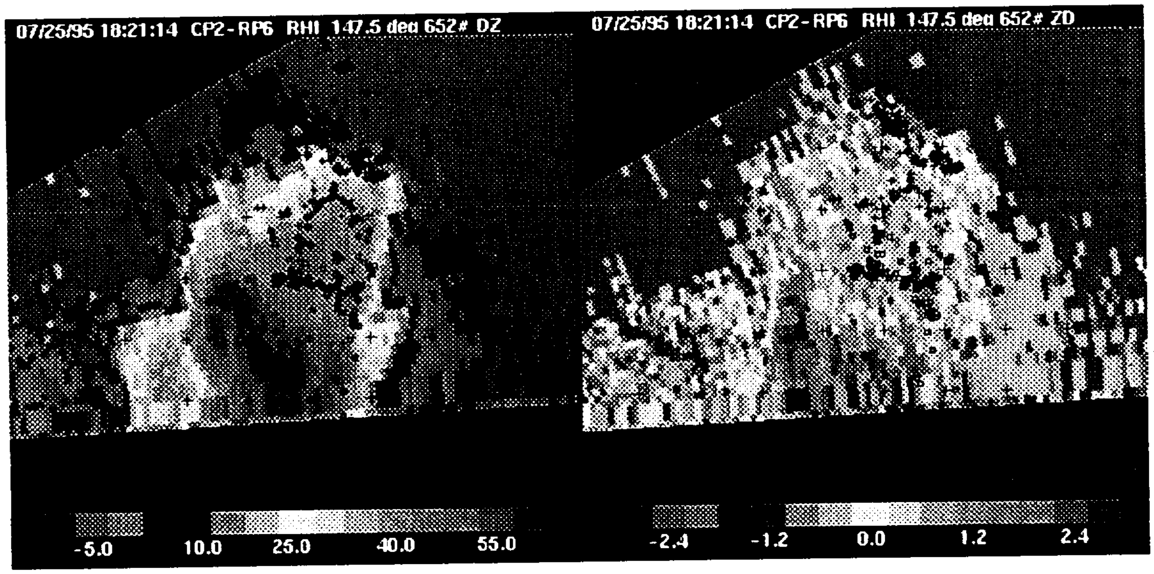

Figure 3. Comparison of successive CG and IC flashes with storm structure, five minutes into the lightning activity.

4. Later in the storm the IC flashes exhibited a well-developed bi-level structure between the negative and upper positive charge regions (Figure 4). Such discharges typically begin with upward propagating negative breakdown and then spread out horizontally at their upper and lower levels [Shao and Krehbiel, 1996]. CG discharges immediately prior to and following the IC flash of Figure 4 removed negative charge at slightly lower altitude (5-7 km) from a region of similar horizontal extent within the storm, as in Figure 3.

5. As the 20 dBZ echo top began its final decay toward the end of the storm, the lightning activity was confined below about 7 km altitude (Figure 1) and consisted of CG and horizontal IC flashes. A typical feature of the storm observations, also seen here, is that a final lightning flash occurs 10-15 minutes or more after the apparent cessation of lightning. In this case the lightning appeared to cease at 18:52:37 but a final, energetic discharge occurred at 19:06:04. During its lifetime the storm developed in a southwesterly direction, and the final flash began in the final, southwest part of the storm and progressed along a meandering 15-km long path back into the earlier part of the storm (Figure 5).

The observations of Figures 1-3 are consistent with those of the initial lightning sequence by Krehbiel et al., [1984]. In addition, they show that the lightning occurred above regions where supercooled liquid precipitation had glaciated, and began shortly after the glaciation. The subsequent lightning activity occurred in regions of ice-form precipitation. These results lend weight to the idea that ice particle interactions cause the electrification. We thank Charles Knight of NCAR for his assistance in making the radar observations.

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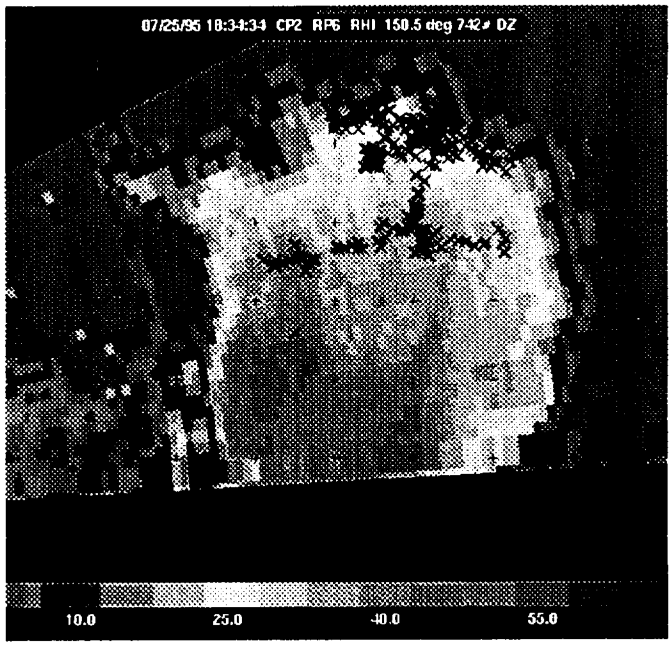

Figure 4. An example of a bi-level IC flash between the main negative and upper positive charge regions, at 18:35:46 in the storm. The bi-level structure is a common feature of mature-storm IC flashes and is also seen in the IC flash of Figure 3.

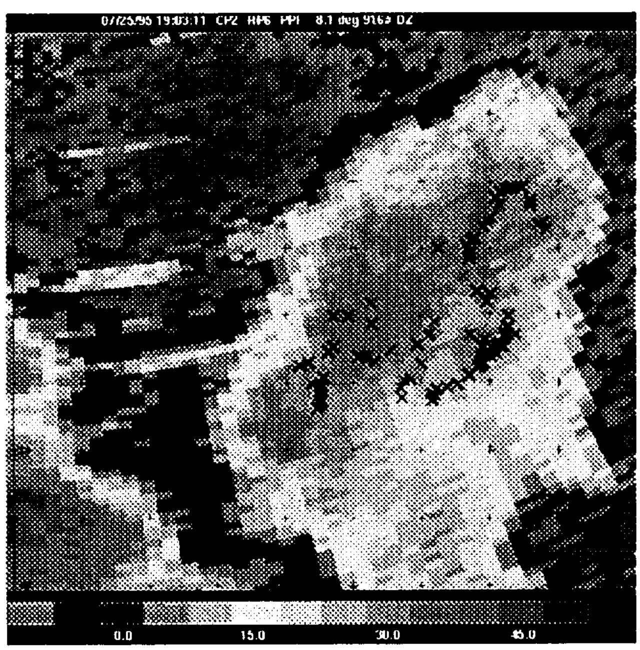

Figure 5. The final flash of the storm, overlaid upon a horizontal PPI scan of the radar reflectivity. The discharge began in the final, SW part of the storm and propagated along a meandering path back into the earlier part of the storm.